NEUROMORPHIC SYSTEM USING THIN-FILM DEVICES

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Artificial intelligences are essential concepts in smart societies, and neural networks are typical schemes that imitate human brains. However, conventionally, neural networks are realized using complicated software and high-spec hardware, whose machine size is large and power consumption is also huge. On the other hand, neuromorphic systems are composed only of customized hardware, whose machine size can be small and power consumption can be reduced.

In this study, neuromorphic systems using thin-film devices, especially with amorphous metal-oxide semiconductor (AOS), have been developed[1]. Here, analog memory, which is utilized as synaptic weight, is proposed. The electrical conductance of the AOS devices is employed as the analogy memory. Moreover, modified Hebbian learning, which is local learning rule without extra control circuits, is proposed. The conductance deterioration of the AOS devices is employed as synaptic plasticity.

First, a Hopfield neural network with AOS devices as crosspoint-type synapse elements has been actually fabricated to confirm the fundamental operation of the neuromorphic system using thin-film devices. It is found that the electric current continuously decreases along the bias time. The Hopfield neural network is really assembled using a field-programmable gate array (FPGA) chip and connecting the AOS devices to the FPGA chip. It is confirmed that a necessary function of the letter recognition is obtained after learning process.

Next, a cellular neural network with AOS devices as layered-type synapse elements has been also actually fabricated. It is again found that the electric current continuously decreases along the bias time. The cellular neural network is also really assembled using a large-scale integration (LSI) chip and depositing the AOS devices on the LSI chip. It is also confirmed that a necessary function of the letter recognition is obtained after learning process.

Once the fundamental operations are confirmed, more advanced functions will be obtained by scaling up the devices and circuits. Therefore, it is expected the neuromorphic systems can be three-dimensional (3D) integration chip, the machine size can be compact, power consumption can be low, and various functions of human brains will be obtained. What has been developed in this study will be the sole solution to realize them.

1. M. Kimura, Cellular neural network formed by simplified processing elements composed of thin-film transistors, Neurocomputing 248, 112, 2017
2. M. Kimura, In-Ga-Zn-O thin-film devices as synapse elements in a neural network, IEEE J. Electron Devices Society, 6, 100, 2017
3. M. Kimura, Neuromorphic hardware using simplified elements and thin-film semiconductor devices, Keynote, CANDAR '17, 56, 2017

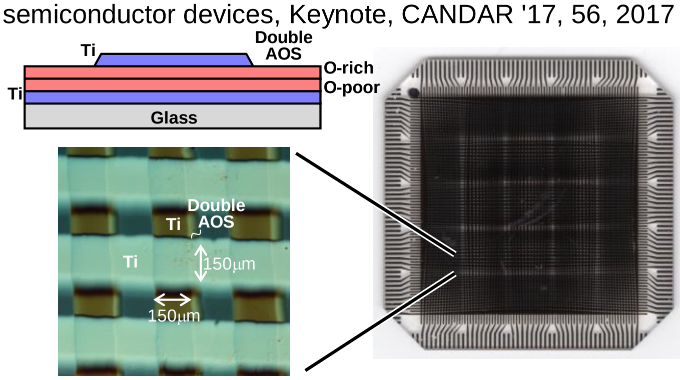

Figure 1 – AOS devices as crosspoint-type synapse elements

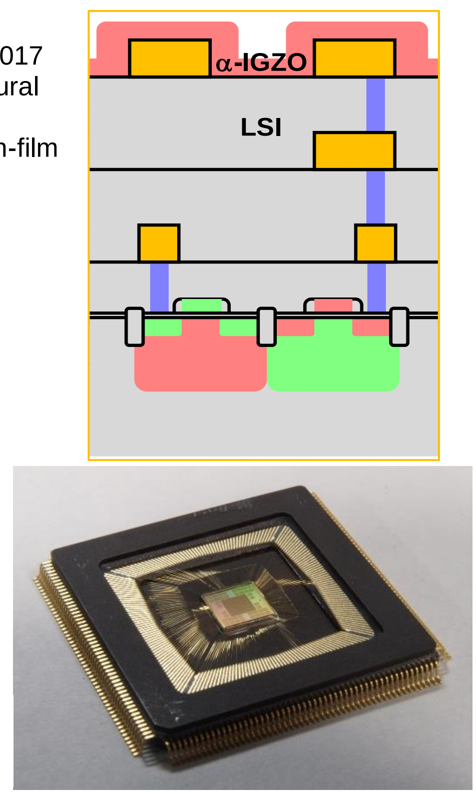

Figure 2 – Neuromorphic system using an LSI chip and AOS devices deposited on it